THE COMPOSITION AND INTERNAL STRUCTURE OF EUROPA; R. C. Ghail, Environmental Science Division, Inst. Env. & Biol. Sci., Lancaster University, Lancaster, LA1 4YQ, UK. *R.Ghail@ic.ac.uk*

The bulk density of Europa, as derived from Voyager data, indicated a bulk composition similar to the Moon or Mars but with the addition of 5 to 10% water. The accepted view was that this water is distributed as a layer of ice ~150 km thick [1] at the surface. Debate has continued as to whether this layer is partly liquid. Ransford [2] was the first to suggest that this model may be too simplistic and proposed that there may also be a hydrated silicate layer. However, a full cosmochemical treatment of Europa (or any galilean satellite) has not be conducted. This abstract presents the results of a simple model of Europa derived from the composition of a chondrite appropriate to its position in the proto-jovian nebula. This model assumes full differentiation into core, mantle, crust and cryosphere and that the internal temperature distribution is such that hydrated silicates are stable to their pressure limited phase boundary (at about 2 GPa). The model has been refined to fit the within the uncertainty limits of mass and radius but is not unique and other possible compositions have yet to be tested. The bulk composition used in the model is listed in Table 1 by weight percent and mole fraction.

The core contains no free Ni-Fe and is composed of almost equal proportions of FeS and FeO, from which a mean density of 5360 kg m^{-3} (~5570 kg m^{-3}, taking into account the approximate core temperature and pressure conditions) is derived. The mass of the core is 18·8 wt% of Europa, which gives a core radius of 732 km.

Table 1. Bulk Composition of Europa.

Constituent	wt%	*f*mol
FeS	7.67	8.716
SiO_2	27.08	45.133
Al_2O_3	2.09	2.049
FeO	20.76	28.833
MgO	17.89	44.725
CaO	2.20	3.929
Na_2O	0.54	0.871
H_2O	16.41	91.167
C	2.50	20.833

The mantle is divided into two layers, the anhydrous eclogite lower mantle and the hydrated amphibolite upper mantle. The normative mineralogy of these two layers is listed in Tables 2 and 3.

For simplicity, the crust is assumed to correspond entirely to the greenschist facies, although it is recognised that the zeolite facies may also be present. The derived mineralogy is listed in Table 4.

The excess H_2O and CO_2 is assumed to accumulate at the surface as a cryosphere or be lost to space. A range of models with different thicknesses of cryosphere can be constructed and tested for their mass and radius. The best fitting model is one in which the cryosphere is 38 km thick, overlying a greenschist crust 73 km thick. The range of cryospheric thickness that fits the uncertainty in Europa's mass is from 23 to 45 km. The amphibolite upper mantle layer is 470 km thick, while the eclogite lower mantle is 256 km thick. The best fitting model is tabulated in Table 5. The total mass of this model is 4·852 x 10^{22} kg.

Table 2. Calculated Mineral Composition of the Eclogite Layer.

Mineral	Formula	*f*mol	wt%
Omphacite	$NaCa(Mg,Fe)AlSi_4O_{12}$	1.742	11.9
Aragonite	$CaCO_3$	2.187	3.5
Almandine-Pyrope Garnet	$(Mg,Fe)_3Al_2Si_3O_{12}$	1.178	8.2
Enstatite-Ferrosilite Pyroxene	$(Mg,Fe)SiO_3$	16.454	29.2
Forsterite-Fayalite Olivine	$(Mg,Fe)_2SiO_4$	18.177	47.2

The mean density of this composition is 3430 kg m^{-3} (~3500 kg m^{-3} at lower mantle temperatures and pressures).

Table 3. Calculated Mineral Composition of the Amphibolite Layer.

Mineral	Formula	*f*mol	wt%
Hornblende	$CaNa_2(Mg,Fe)_4Al_2Si_7O_{22}(OH)_2$	0.871	10.9
Aragonite	$CaCO_3$	3.058	4.4
Almandine-Pyrope Garnet	$(Mg,Fe)_3Al_2Si_3O_{12}$	1.178	7.4
Serpentine	$(Mg,Fe)_3Si_2O_5(OH)_4$	16.001	71.9
Anthophyllite	$(Mg,Fe)_7Si_8O_{22}(OH)_2$	0.437	5.4

The mean density of this composition is 2717 kg m^{-3} (~2740 kg m^{-3} at upper mantle temperatures and pressures).

The derived model indicates that Europa may not have a thick cryosphere that would obscure any underlying silicate geological features but may have a cryospheric thickness comparable in scale to the topography on the silicate surface. Recent Galileo images of Europa support the possibility of volcanic and tectonic silicate-ice interaction. Topographic features on the silicate surface may allow oceanic basins to form in which any liquid water may collect, and continental regions in direct contact with the ice. Tectonic processes in the silicate layer could provide a direct source of traction on the ice. Perhaps more importantly, volcanic processes on the silicate surface could penetrate and liquefy the ice, causing ice diapirism and volcanism. Oceanic regions would be buffered by the water layer, and so would not suffer directly from volcanism. However, traction forces could still be transmitted through the ice as continental areas drift, providing a possible mechanism for regional fracturing. Tidal "seas" on the edges of continental areas would enhance the tidal stresses induced in the ice, causing frequent multiple fracturing which might appear as chaotic terrain.

Two types of silicate volcanism are conceivable: deep plumes from the warmer anhydrous eclogite layer may erupt basalts and picrites at the silicate surface. Secondly, very low fraction partial melts, principally kimberlite and carbonatite, from within the hydrated layer may erupt at the surface. Higher fraction partial melts, principally granitic, would intrude to near the surface of the silicate crust. Tectonic processes may allow for basaltic plate tectonic processes as on Earth, but would more likely resemble continental tectonics, with continental type rifting and obducted plateau collisional regions, both of which would have visible effects on the ice layer.

It is important to stress that this model is derived from only one meteoritic composition. Cosmochemical modelling of the proto-jovian nebula needs to be undertaken to better determine the likely composition of all the galilean satellites. The rate of tidal energy production is also uncertain and highly sensitive to initial assumptions. Thus the internal temperature structure and energy available to drive volcanic and tectonic processes is uncertain. Furthermore, the rheological properties of hydrated silicates are poorly defined. However, while caution must be exercised with any model of Europa, this model does indicate that a previously unrecognised range of processes may generate observable geological features on the surface of Europa.

References: [1] Burns, J.A., and Matthews, M.S., 1986, Satellites, *The University of Arizona Press*, Tucson, 1021 pp. [2] Ransford, G.A., Finnerty, A.A., and Collerson, K.D., 1981, *Nature, 289*, 21-24

Table 4. Calculated Mineral Composition of the Greenschist Layer.

Mineral	Formula	*f*mol	wt%
Paragonite (White Mica)	$NaAl_3Si_3O_{10}(OH)_2$	0.564	3.0
Albite	$NaAlSi_3O_8$	1.178	4.3
Dolomite	$Ca(Mg,Fe)(CO_3)_2$	3.929	10.8
Serpentine	$(Mg,Fe)_3Si_2O_5(OH)_4$	16.150	70.8
Talc	$(Mg,Fe)_3Si_4O_{10}(OH)_2$	1.902	11.1

The mean density of this composition is 2622 kg m^{-3} (~2630 kg m^{-3} at crustal temperatures and pressures).

Table 5. Mass Distribution and Interior Structure of Europa.

Layer	Radius	Density	Mass
Wuestite-Troilite Core	732 km	5570 kg m^{-3}	9.15×10^{21} kg
Eclogite Lower Mantle	988 km	3500 kg m^{-3}	8.39×10^{21} kg
Amphibolite Upper Mantle	1458 km	2740 kg m^{-3}	2.450×10^{22} kg
Greenschist Crust	1531 km	2630 kg m^{-3}	5.39×10^{21} kg
Cryosphere	1569 km	950 kg m^{-3}	1.09×10^{21} kg